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ए सी प्रणालियों में उपयोग के लिए उच्च वोल्टता इंसुलेटरों के कृत्रिम प्रदूषण परीक्षण

(प्रथम पुनरीक्षण)

Indian Standard

ARTIFICIAL POLLUTION TEST ON HIGH VOLTAGE INSULATORS TO BE USED ON AC SYSTEMS

(First Revision)

UDC 621.315.62.027.3:620.193.27

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

February 1995 **Price Group 11**

NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 507 (1991) 'Artificial pollution tests on high voltage insulators to be used on a.c. systems' issued by the International Electrotechnical Commission was adopted by the Bureau of Indian Standards on the recommendation of the Electrical Insulators and Accessories Sectional Committee (ETD 06) and approval of the Electrotechnical Division Council.

This standard was first issued in 1978 in order to dessiminate the details of some basic test procedures so that more experience could be gained to indicate whether those tests were suitable for inclusion as type tests in future Indian Standards on insulators. The revision of this standard has been taken up in order to update the test procedures for pollution tests applicable to insulators for overhead power lines, sub-stations, traction lines and to HT bushings for electrical equipments.

The text of IEC Standard has been approved as suitable for publication as Indian Standard without deviations. Certain terminology and conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC Pub 60-1 (1989) High voltage test techniques : Part 1 General definitions and test requirements	IS 2071 (Part 1) : 1993 High voltage test techniques : Part 1 General definitions and test requirements (*second revision*)	Identical
IEC Pub 60-2 (1973) High voltage test techniques : Part 2 Procedures	IS 2071 (Part 2) : 1974 Methods of high voltage testing : Part 2 Test procedures (*first revision*)	Technically equivalent
IEC Pub 71-1(1976) Insulation coordination : Part 1 Terms, definitions, principles and rules	IS 2165 (Part 1) : 1977 Insulation coordination : Part 1 Phase to earth insulation coordination principles and rules (*second revision*) ; and IS 2165 (Part 2): 1983 Insulation coordination : Part 2 Phase to phase insulation coordination principles and rules	Technically equivalent

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

(Continued on third cover)

Indian Standard

ARTIFICIAL POLLUTION TEST ON HIGH VOLTAGE INSULATORS TO BE USED ON AC SYSTEMS

(First Revision)

SECTION ONE - GENERAL

1 Scope

This standard is applicable for the determination of the power frequency withstand characteristics of ceramic and glass insulators to be used outdoors and exposed to polluted atmospheres, on a.c. systems with the highest voltage of the system ranging from 1 000 V up to 765 kV.

These tests are not directly applicable to greased insulators or to special types of insulators (insulators with conductive glaze or covered with any organic insulating material).

2 Object

The object of this standard is to prescribe procedures for artificial pollution tests applicable to insulators for overhead lines, substations and traction lines, and to bushings.

3 Definitions

For the purpose of this standard, the following definitions apply.

3.1 *Test voltage*

The r.m.s. value of the voltage with which the insulator is continuously energized throughout the test.

3.2 *Short-circuit current (I_{sc}) of the testing plant*

The r.m.s. value of the current delivered by the testing plant when the test object is short-circuited at the test voltage.

3.3 *Specific creepage distance (L_s) of an insulator*

The overall creepage distance *L* of an insulator divided by the product of the test voltage and $\sqrt{3}$; it is generally expressed in mm/kV.

3.4 *Form factor of an insulator (F)*

The form factor is determined from the insulator dimensions. For graphical estimation of the form factor, the reciprocal value of the insulator circumference (l/p) is plotted versus the partial creepage distance *l* counted from the end of the insulator up to the point reckoned.

The form factor is given by the area under this curve and calculated according to the formula:

$$F = \int_0^L \frac{dl}{p(l)}$$

3.5 *Salinity (S_a)*

The concentration of the solution of salt in tap water, expressed by the amount of salt divided by the volume of solution; it is generally expressed in kg/m³.

3.6 *Pollution layer*

A conducting electrolytic layer on the insulator surface, composed of salt plus inert materials.

The conductance of the pollution layer on the insulator is measured in accordance with 16.1.

3.7 *Layer conductivity (K)*

The conductance of the pollution layer multiplied by the form factor; it is generally expressed in µS.

3.8 *Salt deposit density (SDD)*

The amount of salt in the deposit on a given surface of the insulator (metal parts and assembling materials are not to be included in this surface), divided by the area of this surface (see 16.2); it is generally expressed in mg/cm².

3.9 *Degree of pollution*

The value of the quantity (salinity, layer conductivity, salt deposit density) which characterizes the artificial pollution applied to the tested insulator.

3.10 *Reference salinity*

The value of the salinity used to characterize a test.

3.11 *Reference layer conductivity*

The value of the layer conductivity used to characterize a test: it is defined as the maximum value of the conductivity of the wetted layer of an insulator energized only for performing the conductance measurements.

3.12 *Reference salt deposit density*

The value of the salt deposit density used to characterize a test: It is defined as the average of the salt deposit density values measured on a few insulators (or on parts of them), which are chosen for this purpose from among the contaminated ones prior to their submission to any test.

3.13 *Specified withstand degree of pollution*

The reference degree of pollution at which an insulator shall withstand the specified test voltage in at least three tests out of four, under the conditions described in the relevant clauses 11 or 19.

3.14 *Maximum withstand degree of pollution*

The highest degree of pollution at which at least three withstand tests out of four can be obtained at the specified test voltage, under the conditions described in the relevant clauses 11 or 19.

3.15 *Specified withstand voltage*

The test voltage at which an insulator shall withstand the specified degree of pollution in at least three tests out of four, under the conditions described in the relevant clauses 11 or 19.

3.16 *Maximum withstand voltage*

The highest test voltage at which at least three withstand tests out of four can be obtained at the specified degree of pollution, under the conditions described in the relevant clauses 11 or 19.

SECTION TWO - GENERAL TEST REQUIREMENTS

4 Test methods

The two following categories of pollution test methods are recommended for standard tests:

- the salt fog method (section three) in which the insulator is subjected to a defined ambient pollution;
- the solid layer method (section four) in which a fairly uniform layer of a defined solid pollution is deposited on the insulator surface.

NOTE - In these test methods the voltage is held constant for a period of at least several minutes. Variants in which the voltage is raised continuously to flashover are not standardized but may be used for special purposes.

5 Arrangement of insulator for test

5.1 *Test configuration*

The insulator shall be erected in the test chamber, complete with the metal fittings which are invariably associated with it. The vertical position is in general suggested for comparison of different insulator types. Tests in other positions (inclined, horizontal) duplicating actual service conditions may be carried out when agreed between the manufacturer and the purchaser. When there are special reasons not to test insulators in the vertical position (e.g. wall bushings and circuit-breaker longitudinal insulation), only the service position shall be considered.

The minimum clearances between any part of the insulator and any earthed object other than the structure which supports the insulator and the columns of the nozzles, when used, shall be not less than 0,5 m per 100 kV of the test voltage and in any case not less than 1,5 m.

The configurations of the supporting structure and the energized metal parts, at least within their minimum clearance from the insulator, shall reproduce those expected in service. The arrangement of the nozzles and their construction are described in clause 8.

As regards the influence of capacitive effects on the test results, the following considerations can be drawn from the available experience:

- fittings are deemed not to affect the results significantly, at least for test voltages up to 450 kV;
- internal high capacitance can have some effect on the external surface behaviour, particularly in tests with solid layer methods.

5.2 *Cleaning of insulator*

The insulator shall be carefully cleaned so that all traces of dirt and grease are removed. After cleaning, the insulating parts of the insulator shall not be touched by hand.

NOTE - If necessary, the metal parts and the assembling materials should be painted with a salt water resistant paint to ensure that no corrosion products wash down onto the insulating surface during the test.

Water, preferably heated to about 50 °C, with the addition of trisodium phosphate or another detergent, shall be used, after which the insulator is to be thoroughly rinsed with tap water. The surface of the insulator is deemed to be sufficiently clean and free from any grease if large continuous wet areas are observed.

Before every subsequent contamination the insulator shall be again thoroughly washed with tap water only, to remove all traces of pollution.

6 Requirements for the testing plant

6.1 *Test voltage*

The frequency of the test voltage shall be between 48 Hz and 62 Hz.

In general the test voltage coincides with the highest voltage (phase to earth value) the insulator is required to withstand under normal operating conditions. For equipment, it is equal to $U_m/\sqrt{3}$, U_m being the highest voltage for equipment (see IEC 71-1). It is higher than this value when testing insulators for phase to phase configurations or for isolated neutral systems.

6.2 *Minimum short-circuit current*

In the artificial pollution tests, the testing plant needs a short-circuit current (I_{sc}) higher than in other types of insulator tests. This means that I_{sc} must have a minimum value which varies with the test conditions; moreover there are also requirements on other parameters of the testing plant.

The minimum value of I_{sc} ($I_{sc\ min}$) is given in figure 1 as a function of the electrical surface stress of the insulator under test, expressed in terms of its specific creepage distance L_s.

Besides the above requirement of $I_{sc\ min}$ value, the testing plant shall comply with the two following conditions:

- resistance/reactance ratio (R/X) equal to or higher than 0,1;
- capacitive current/short-circuit current ratio(I_c/I_{sc}) within the range 0,001 - 0,1.

More information on the criteria followed to assess the above requirements is given in appendix A.

When the value of I_{sc} of the testing plant, although higher than 6 A, does not comply with the limits given in figure 1, the verification of a specified withstand characteristic of a polluted insulator (see clauses 11 and 18) or the determination of its maximum withstand characteristic (see appendix B) can still be performed, provided that the source validity is directly ascertained by the following check.

In each individual test of this investigation, the highest leakage current pulse amplitude is recorded and its maximum value ($I_{h\ max}$) determined considering the three tests resulting in withstand, in the withstand conditions.

The $I_{h\ max}$ value shall comply with the expression below:

$$I_{sc}/I_{h\ max} \geq 11$$

I_{sc} being given in r.m.s. and $I_{h\ max}$ in peak value.

More details are given in appendix A.

Since the leakage currents can be used for the interpretation of the results, it is recommended that suitable devices be arranged in order to record these currents during artificial pollution tests.

SECTION THREE - SALT FOG METHOD

7 Salt solution

The salt solution shall be made of sodium chloride (NaCl) of commercial purity and tap water.

NOTE - Tap water with high hardness, for example with a content of equivalent $CaCO_3$ greater than 350 g/m³, can cause limestone deposits on the insulator surface. In this case the use of deionized water for preparation of the salt solution is recommended.
Hardness of tap water is measured in terms of content of equivalent $CaCO_3$*.

The salinity used shall have one of the following values: 2,5 - 3,5 - 5 - 7 - 10 - 14 - 20 - 28 - 40 - 56 - 80 - 112 - 160 and 224 kg/m³.

The prescribed tolerance error in salinity is ±5 % of the specified value.

It is recommended that the salinity be determined either by measuring the conductivity or by measuring the density with a correction of temperature.

Table 1 gives the correspondence between the value of salinity, volume conductivity and density of the solution at a temperature of 20 °C.

* In accordance with the *Condensed Chemical Dictionary*, revised by G. Hawley - Encyclopedia of Chemistry; Van Nostrand Reinhold Company, New York (USA), 1971.

When the solution temperature is not at 20 °C, conductivity and density values shall be corrected.

The temperature of the salt solution shall be between 5 °C and 30 °C, since no experience is available to validate tests performed outside this range of solution temperature.

Table 1 – Salt-fog method: correspondence between the value of salinity, volume conductivity and density of the solution at a temperature of 20 °C

Salinity S_a kg/m³	Volume conductivity σ_{20} S/m	Density Δ_{20} kg/m³
2,5	0,43	-
3,5	0,60	-
5	0,83	-
7	1,15	-
10	1,6	-
14	2,2	-
20	3,0	-
28	4,1	1 018,0
40	5,6	1 025,9
56	7,6	1 037,3
80	10	1 052,7
112	13	1 074,6
160	17	1 104,5
224	20	1 140,0

The conductivity correction shall be made using the following formula:

$$\sigma_{20} = \sigma_\theta \, [1 - b\,(\theta - 20)]$$

where:

θ is the solution temperature (°C)

σ_θ is the volume conductivity at a temperature of θ °C (S/m)

σ_{20} is the volume conductivity at a temperature of 20 °C (S/m)

b is the factor depending on temperature θ, as given below:

θ(°C)	b
5	0,03156
10	0,02817
20	0,02277
30	0,01905

NOTE - For other values of temperature θ, within the range 5 °C - 30 °C, the factor b is obtained by interpolation.

The density correction shall be made using the following formula:

$$\Delta_{20} = \Delta_{\theta}\,[1 + (200 + 1{,}3\ S_a)\,(\theta - 20) \times 10^{-6}]$$

where:

θ is the solution temperature (°C)

Δ_{θ} is the density at a temperature of θ °C (kg/m³)

Δ_{20} is the density at a temperature of 20 °C (kg/m³)

S_a is the salinity (kg/m³)

This correction formula is only valid for salinities over 20 kg/m³.

8 Spraying system

The fog is produced in the test chamber by means of the specified number of sprays which atomize the solution by a stream of compressed air flowing at right angles to the solution nozzle. The nozzles consist of corrosion resistant tubes, the internal diameter of the air nozzles being 1,2 mm ± 0,02 mm and the internal diameter of the solution nozzle being 2,0 mm ± 0,02 mm. Both nozzles shall have an outside diameter of 3,0 mm ± 0,05 mm and the ends of the nozzles shall be square-cut and polished.

The end of the solution nozzle shall lie on the axis of the air nozzle to within ±0,05 mm. The distance between the end of the compressed air nozzle and the central line of the solution nozzle shall be 3,0 mm ± 0,05 mm. The axes of the two nozzles shall lie in the same plane to within ±0,05 mm.

Figure 2 shows a typical construction of the fog spray nozzle.

The sprays shall be in two columns parallel to and on opposite sides of the insulator which shall have its axis in the same plane as the columns, i.e. a vertical insulator is tested with vertical columns and a horizontal insulator with horizontal columns. In the case of an inclined insulator (see figure 3) the plane containing the insulator and the columns shall intersect the horizontal plane in a line at right angles to the insulator axis; in this case, the axis of the solution nozzles is vertical. The distance between the solution nozzles and the insulator axis shall be 3,0 m ± 0,05 m.

The sprays shall be spaced at 0,6 m intervals, each spray pointing at right angles to the column axis towards its counterpart on the other column and within an angle of 1° to the plane of the sprays. This alignment can be checked for vertical sprays by lowering the solution nozzle, passing water through the air nozzle and directing it towards the opposing spray; afterwards, raising the solution nozzle to the operating position. The mid-point of the insulator shall preferably be in line with the mid-points of the columns of sprays. Both columns shall extend beyond each end of the insulator by at least 0,6 m.

The minimum number N of sprays per column shall be, for a length H in metres of the insulator:

$$N = \frac{H}{0,6} + 3$$

The sprays shall be supplied with filtered, oil-free air at a relative pressure of 700 kPa ± 35 kPa.

The flow of solution to each spray shall be 0,5 dm^3/min ± 0,05 dm^3/min for the period of the test, and the tolerance on the total flow to all sprays shall be ±5 % of the nominal value.

9 Conditions before starting the test

The test shall start while the insulator, cleaned according to 5.2, is still completely wet.

At the start of the test the insulator shall be in thermal equilibrium with the air in the test chamber. In addition, the ambient temperature shall be not less than 5 °C nor greater than 40 °C and its difference from the temperature of the water solution shall not exceed 15 K.

The insulator is energized, the salt-solution pump and air compressor are switched on, and the test is deemed to have started as soon as the compressed air has reached the normal operating pressure at the nozzles.

10 Preconditioning process

The insulator, prepared in the normal way, is subjected to the test voltage at the reference salinity for 20 min, or until the insulator flashes over; if the insulator does not flash over, the voltage is raised in steps of 10 % of the test voltage every 5 min until flashover.

After flashover, the voltage is reapplied and raised as quickly as possible to 90 % of the previously obtained flashover voltage, and thereafter increased in steps of 5 % of the initial flashover voltage every 5 min until flashover. The last process is repeated six further times, in each of them the voltage is raised rapidly to 90 % of the last obtained flashover voltage and then in steps of 5 % every 5 min until flashover. After the eight flashovers, the fog shall be cleared, the insulator shall be washed down with tap water and then the withstand test (see clause 11) shall start as soon as possible.

The characteristics of the voltage source in the preconditioning process shall be not lower than those used as references in the withstand test (see clause 6).

If the preconditioning process performed at the reference salinity requires excessively high voltages, the use of higher values of salinity for the preconditioning is allowed. If, in spite of this expedient, the voltage required remains too high, shorter sections of the insulator may be separately preconditioned using adequate procedures to avoid overstressing of the internal insulation, if any (e.g. in the case of arresters or bushings).

11 Withstand test

The object of this test is to confirm the specified withstand salinity of the insulator at the specified test voltage.

The test shall start when the test insulator and the chamber conditions fulfil the requirements given in clause 9 and after the preconditioning of the insulator according to clause 10.

A series of tests are performed on the insulator at the specified test voltage, using a salt solution having the specified test salinity in accordance with clause 7. The duration of each test shall be 1 h, if no flashover occurs before that time has elapsed. The insulator shall be carefully washed with tap water before each subsequent test.

12 Acceptance criterion for the withstand test

The insulator complies with this specification if no flashover occurs during a series of three consecutive tests in accordance with the procedure in clause 11. If only one flashover occurs, a fourth test shall be performed and the insulator then passes the test if no flashover occurs.

NOTE - For research purposes the withstand characteristics of an insulator can be determined. Practices for assessing or checking these characteristics are given in appendix B.

SECTION FOUR - SOLID LAYER METHODS

13 Composition of the contaminating suspension

A suspension shall be prepared using one of the two following compositions:

13.1 *Kieselguhr composition*

It consists of:

- 100 g Kieselguhr (diatomaceous earth, diatomite), see clause 14;
- 10 g highly-dispersed silicon dioxide, particle size 2-20 nm;
- 1 000 g tap water;
- a suitable amount of NaCl of commercial purity.

When the volume conductivity of tap water is higher than 0,05 S/m, the use of demineralized water is recommended.

To achieve the reference degree of pollution on the insulator under test, with the prescribed tolerance of ±15 %, an appropriate value of volume conductivity of the prepared suspension is to be determined by submitting the insulator itself (or a part of it) to preliminary contamination trials. The desired volume conductivity is reached by adjusting the amount of salt in the suspension. As an approximate guide to start the trials, table 2 below gives an approximate correspondence between the reference degree of pollution on the insulator and the volume conductivity of the suspension at a temperature of 20 °C.

Table 2 – Kieselguhr composition: approximate correspondence between the reference degrees of pollution on the insulator and the volume conductivity of the suspension at a temperature of 20 °C

Reference degrees of pollution for Kieselguhr composition		Volume conductivity of the suspension
Salt deposit density *SDD* mg/cm²	Layer conductivity K_{20} µS	σ_{20} S/m
0,0176	7	0,21
0,025	10	0,30
0,0353	14	0,42
0,005	20	0,60
0,0705	28	0,85
0,1	40	1,20
0,141	56	1,69
0,20	80	2,40

13.2 *Kaolin (or Tonoko) composition*

It consists of:

- 40 g Kaolin (or Tonoko), see clause 14;
- 1 000 g tap water;
- a suitable amount of NaCl of commercial purity.

When the volume conductivity of tap water is higher than 0,05 S/m, the use of demineralized water is recommended.

To achieve the reference degree of pollution on the insulator under test, with the prescribed tolerance of ±15 %, an appropriate value of volume conductivity of the prepared suspension is to be determined by submitting the insulator itself (or part of it) to preliminary contamination trials. The desired volume conductivity is reached by adjusting the amount of salt in the suspension.

As an approximate guide to start the trials, table 3 below gives an approximate correspondence between the reference degree of pollution on the insulator and the volume conductivity of the suspension at a temperature of 20 °C, in the case of standard cap and pin insulators contaminated in a vertical position in normal ambient conditions. The volume conductivity required for other insulators can vary from the values given in table 3.

Table 3 – Kaolin (or Tonoko) composition: approximate correspondence between the reference degrees of pollution on the insulator and the volume conductivity of the suspension at a temperature of 20 °C

Reference degrees of pollution for Kaolin (or Tonoko) composition		Volume conductivity of the suspension
Salt deposit density *SDD* mg/cm²	Layer conductivity K_{20} µS	σ_{20} S/m
0,025	3	1
0,035	4,2	1,4
0,05	5,5	2
0,07	8	2,8
0,1	11	4
0,14	14,5	5,6
0,2	20	8
0,28	27	11,2
0,4	37	16

14 Main characteristics of inert materials

Ranges of values for the main characteristics of the types of Kieselguhr, Kaolin and Tonoko that are used for the suspensions are given in the following table 4.

Inert materials having other names, but whose characteristics are proved to match with the same ranges of one of the above-mentioned types, may be used in place of that type.

Table 4 – Main characteristics of the inert materials used in solid layer suspensions

Type of inert material	Weight composition %				Granulometry (cumulative distribution) µm			Volume conductivity σ_{20} S/m
	SiO_2	Al_2O_3	Fe_2O_3	H_2O	16 %	50 %	84 %	
Kieselguhr	70-90	5-25	0,5-6	7-14	0,1-0,2	0,4-1	2-10	0,0015-0,02
Kaolin	40-50	30-40	0,3-2	7-14	0,1-0,2	0,4-1	2-10	0,0015-0,02
Tonoko	60-70	10-20	4-8	–	0,8-1,5	3-5	8-15	0,002-0,01

NOTES

1 Granulometry distribution gives the values of the hole diameter of a sieve in µm through which one of the quoted percentages of the total mass of particles passes.

2 Volume conductivity for the characterization of inert material is determined with the use of demineralized water.

15 Application of the pollution layer

The suspension prepared using one of the compositions described in clause 13 shall be applied by spraying or flowing on the dry insulator, previously cleaned according to 5.2, to obtain a reasonably uniform layer. Alternatively the insulator may be dipped in the suspension, provided its size makes this operation possible.

NOTES

1 The use of a probe (see appendix C) is suggested for a check on the wet layer, when the uniformity does not appear to be satisfactory during visual examination.

2 The artificial layer may be applied on the insulator surface by spraying the prepared suspension through one or two nozzles of a commercial type spray gun. The direction of the spray nozzles shall be adjusted to ensure a reasonably uniform layer on the whole insulator surface. A distance of about 20 cm to 40 cm between the spray nozzle outlet and the rim of the insulator shed has been found satisfactory. It is desirable to keep the suspension stirred.

The required degree of pollution on the insulator may be obtained by repeated applications.

3 The coating time can be reduced by preheating the insulator. In this case the complete insulator should be in thermal equilibrium with the air in the test chamber at the start of the test. The coating time can also be reduced by drying the layer between successive applications.

Other techniques are suitable and can also be used. For instance the practice of flooding the prepared suspension over the insulator surface, until it is flowing-on ("flow-on" technique), is particularly suitable for large or long insulators, when Kaolin or Tonoko compositions are used.

4 A preconditioning process, as specified for the salt fog test, is not necessary with the solid layer methods. More details are given in clause D.1.

The layer shall be left to dry prior to the submission of the insulator to the test. More details are given in clause D.2.

16 Determination of the degree of pollution of the tested insulator

The degree of pollution of the tested insulator, expressed in terms of layer conductivity or salt deposit density, is determined as follows.

16.1 *Layer conductivity (K)*

As already mentioned, the layer conductivity is calculated by multiplying the layer conductance measured on the unenergized insulator by its form factor.

The layer conductance measurement is repeated on the insulator during its wetting, with the aim of determining the maximum value reached.

Each measurement of the layer conductance consists of applying to the insulator a voltage not lower than 700 V r.m.s. per metre of overall creepage distance and measuring the current flowing through the wet layer. The voltage must be applied only long enough to read the meter.

When higher voltage values are used, the measuring time shall be short enough to avoid serious error due to heating or drying of the pollution layer. To this aim it shall be checked that neither surge activity nor amplitude variations affect the shape of the measured current.

The layer conductivity shall be related to the reference temperature of 20 °C, using the following formula:

$$K_{20} = K_\theta \, [1 - b\,(\theta - 20)]$$

where:

θ is the temperature of the insulator surface (°C)

K_θ is the layer conductivity at a temperature of θ °C (μS)

K_{20} is the layer conductivity at a temperature of 20 °C (μS)

b is the factor already defined in clause 7.

16.2 *Salt deposit density (SDD)*

The deposit is removed and carefully collected from the surface of a separate insulator (or from a part thereof), identical to the tested one and contaminated in the same way. The whole surface of this insulator, or the upper and lower surfaces separately, are cleaned for this purpose, excluding metal parts. More details are given in clause D.6.

In the case where only one cylindrical insulator is available for test, measurement of salt deposit density is made on a few of its sheds. Thereafter, the cleaned surface shall be re-polluted by re-applying the pollution layer.

After the contaminating operation on the insulator (or part thereof) chosen for *SDD* measurement, the drops shall be removed carefully before drying the layer. In this way, errors can be avoided in quantifying the degree of pollution really effective in the test.

The deposit is then dissolved in a known quantity of water, preferably demineralized water. The resulting suspension is kept stirred for at least 2 min before the measurement of its volume conductivity σ_θ (S/m) at the temperature θ (°C). Then the value σ_{20} is obtained from σ_θ by the same relationship as that given in clause 7.

The salinity S_a (kg/m³) of the suspension is determined, when σ_{20} is within the range 0,004-0,4 S/m, by the use of the following formula:

$$S_a = (5{,}7\,\sigma_{20})^{1{,}03}$$

The salt deposit density *SDD* (mg/cm²) is then obtained by the following formula:

$$SDD = \frac{S_a \cdot V}{A}$$

where:

V is the volume of the suspension (cm³)
A is the area of the cleaned surface (cm²)

17 General requirements for the wetting of the pollution layer

The test object shall be wetted by means of fog generators which provide an uniform fog distribution over the whole length and all around the test object. The temperature of the test object at the beginning of the wetting shall be within ±2 K of the ambient temperature in the test chamber. A plastic tent, surrounding the test object, may be used to limit the volume of the test chamber.

The fog generation in the test chamber shall be maintained until the end of each individual test at a constant steady rate of flow.

After a certain degree of wetting of the pollution layer is reached, moisture starts to drip from the edges of insulator sheds; thus some pollutant content is removed from the layer and a progressive washing of the test object can be expected.

18 Test procedures

Two alternative procedures are proposed, basically differing in the layer conditions, wet or dry, of the test object at the instant at which the test voltage is applied to it.

The main rules relevant to the two test procedures are given below.

18.1 *Procedure A - Wetting before and during energization*

For this procedure, the insulator is contaminated using either Kieselguhr composition (see 13.1) or Kaolin (or Tonoko) composition (see 13.2). The degree of pollution is generally expressed in terms of layer conductivity, but the salt deposit density may be used also.

The insulator is prepared for the test according to clause 15 and placed in its test position in the chamber, when the fog generation is started.

Steam fog should preferably be used to wet the pollution layer.

A steam fog generator, consisting of a distribution pipe, with nozzles spaced at equal distance, is shown in figure 4, as an example.

NOTE - Instead of the steam fog, it is permitted to use a fog generated with nozzles spraying warm or cold water (see as an example the device in figure 2), provided that this fog gives the recommended uniform wetting.

When this variant is used, before starting the test, cooling of the test object may be advantageous.

For the evaluation of the layer conductivity, layer conductance measurements are performed on the test object according to 16.1.

The flow rate of the fog input in the chamber, at normal ambient temperature, shall be sufficiently high to ensure that the layer conductivity reaches its maximum value within 20 min to 40 min from the start of the fog generation. The maximum value of the layer conductivity measured in the test is assumed to be the reference layer conductivity.

The test voltage is then applied, either instantaneously or during a time not exceeding 5 s, and maintained until flashover, or for 15 min if no flashover occurs.

The insulator is then removed from the fog chamber and allowed to dry. It is placed for the second time in the chamber and re-wetted by the fog until the layer conductivity reaches its maximum value; if this is not lower than 90 % of the above-mentioned reference value,

the test voltage is applied again and maintained until flashover, or for 15 min if no flashover occurs; if it is lower than 90 %, the pollution layer shall be applied again to the insulator, according to clause 15.

No more than two consecutive tests shall be performed on an insulator with the same pollution layer.

18.2 *Procedure B - Wetting after energization*

For this procedure, the insulator is contaminated using Kaolin (or Tonoko) composition (see 13.2). The degree of pollution is generally expressed in terms of salt deposit density (see 16.2).

NOTE - Measurements of the layer conductance are generally not requested. On agreement between the manufacturer and the purchaser, they may be performed during the wetting on a separate, unenergized insulator, identical to the one tested (or to a part of it) and contaminated in the same way.

The insulator is prepared for the test according to clause 15 and placed in its test position in the chamber with the pollution layer still dry.

Steam fog shall be used for wetting the pollution layer.

The fog generators shall be under the test object as close as possible to the floor level. In all cases they shall be at least 1 m away from the test object and their flow shall not be directed towards it.

The steam input rate in the chamber shall be zero until the test voltage is applied and constant thereafter. At normal ambient temperature, the steam input rate shall be within the range 0,05 kg/h ± 0,01 kg/h per cubic metre of the test chamber volume. In particular test conditions this value may need some adjustment through a direct check of the wetting action of the fog as described in clause D.3.

The test voltage is maintained until flashover occurs. Otherwise it is maintained for 100 min from the start of the test or until the current peaks, if they are measured, have decreased to values permanently lower than 70 % of the maximum peak recorded. More details are given in clauses D.4 and D.5.

For this procedure the pollution layer is used only once.

19 Withstand test and acceptance criterion (common to both Procedures A and B)

The object of this test is to confirm the specified withstand degree of pollution at the specified test voltage. The insulator complies with this specification if no flashover occurs during three consecutive tests performed in accordance with 18.1 for Procedure A or with 18.2 for Procedure B.

If only one flashover occurs, a fourth test shall be performed and the insulator then passes the test if no flashover occurs.

NOTE - For research purposes the withstand characteristics of an insulator can be determined. Practices for assessing or checking these characteristics are given in appendix B.

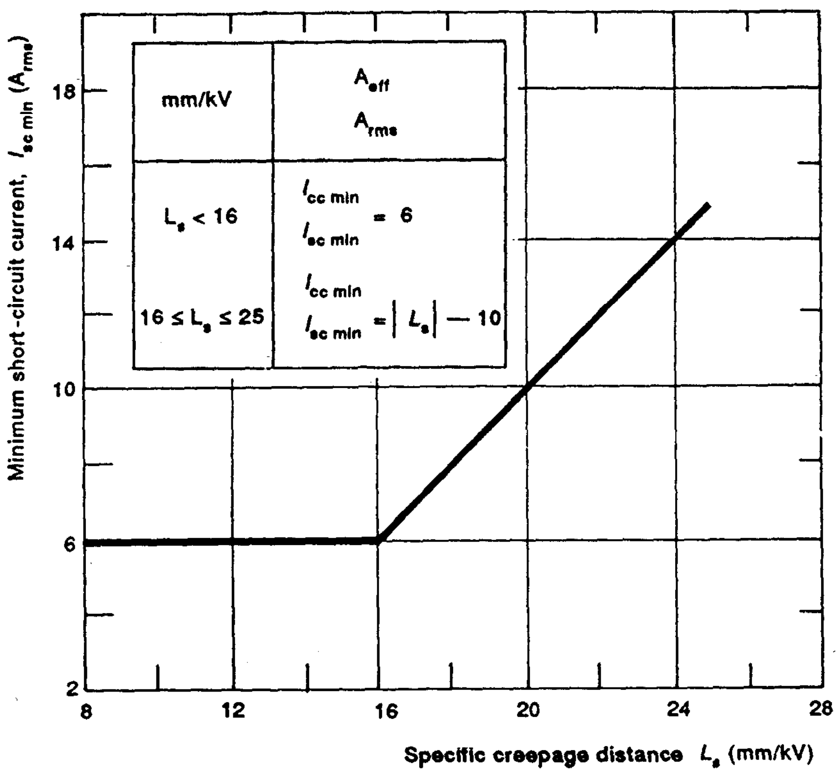
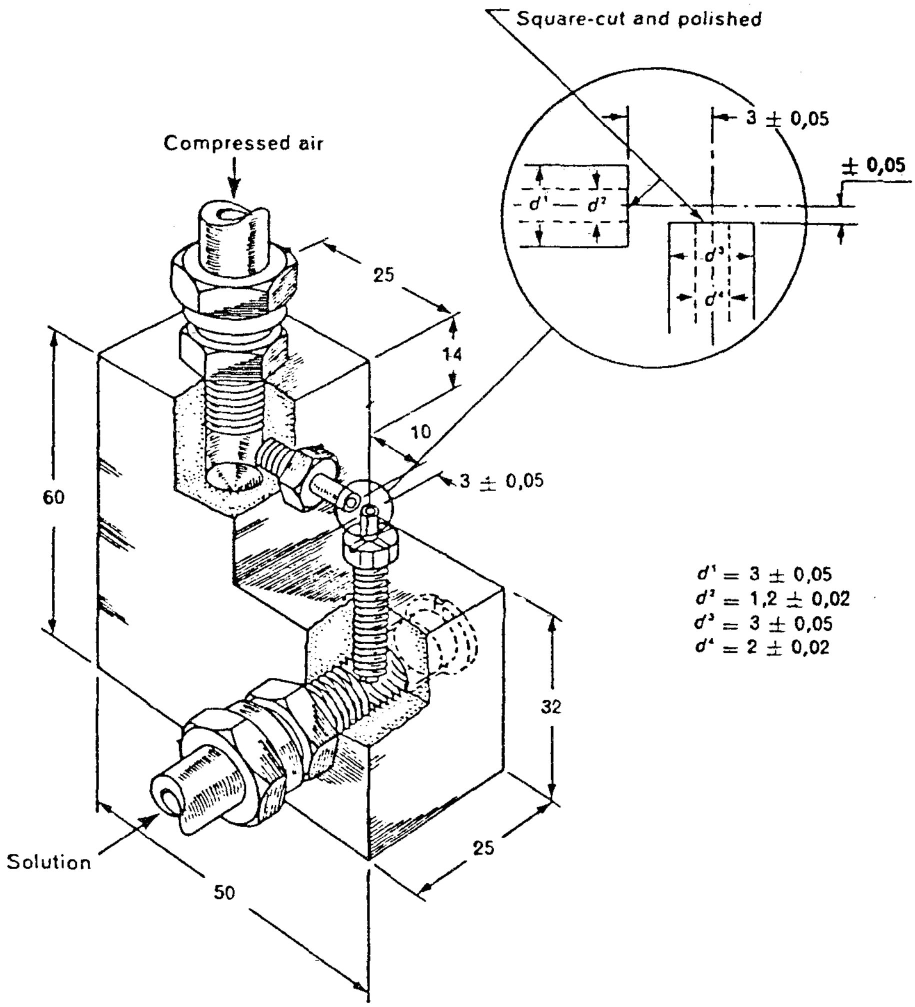


Figure 1 – Minimum short-circuit current, $I_{sc\ min}$, required for the testing plant, as a function of the specific creepage distance, L_s, of the insulator under test. (The available experience is deemed insufficient to give $I_{sc\ min}$ values for tests at specific creepage distances higher than 25 mm/kV.)



Dimensions in millimetres

Figure 2 – Typical construction of fog spray nozzle

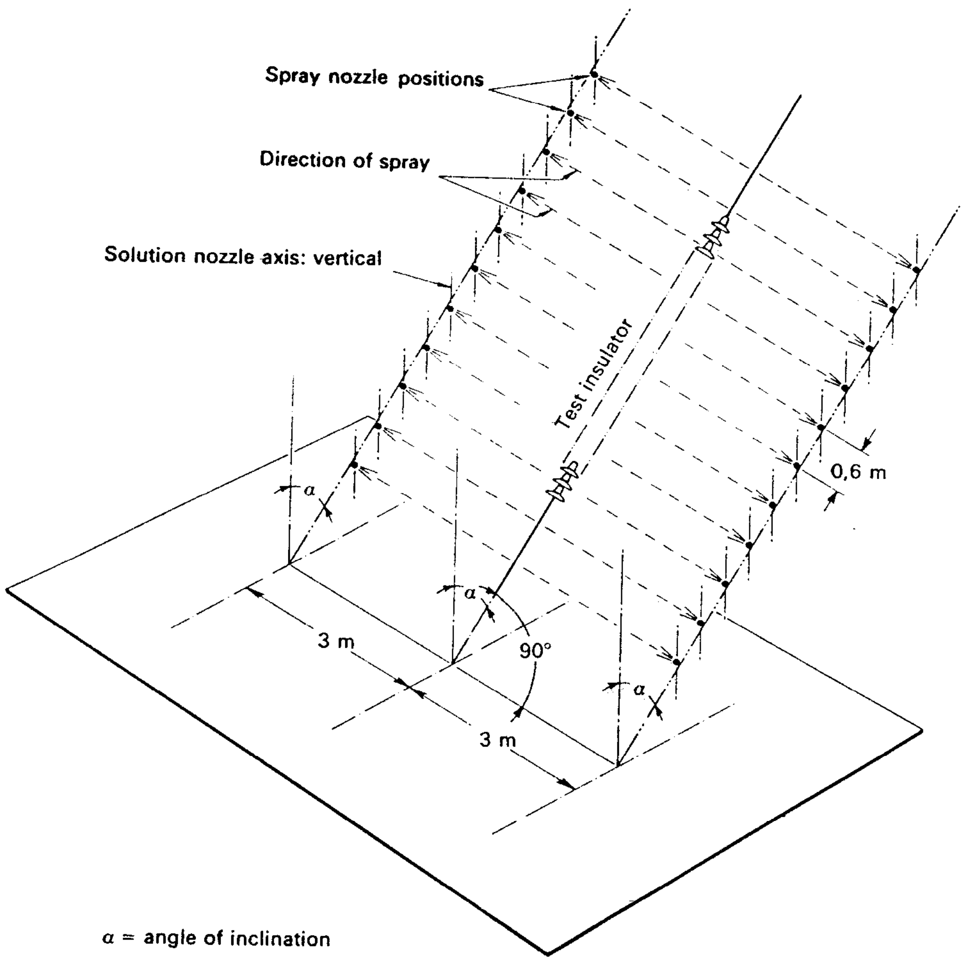
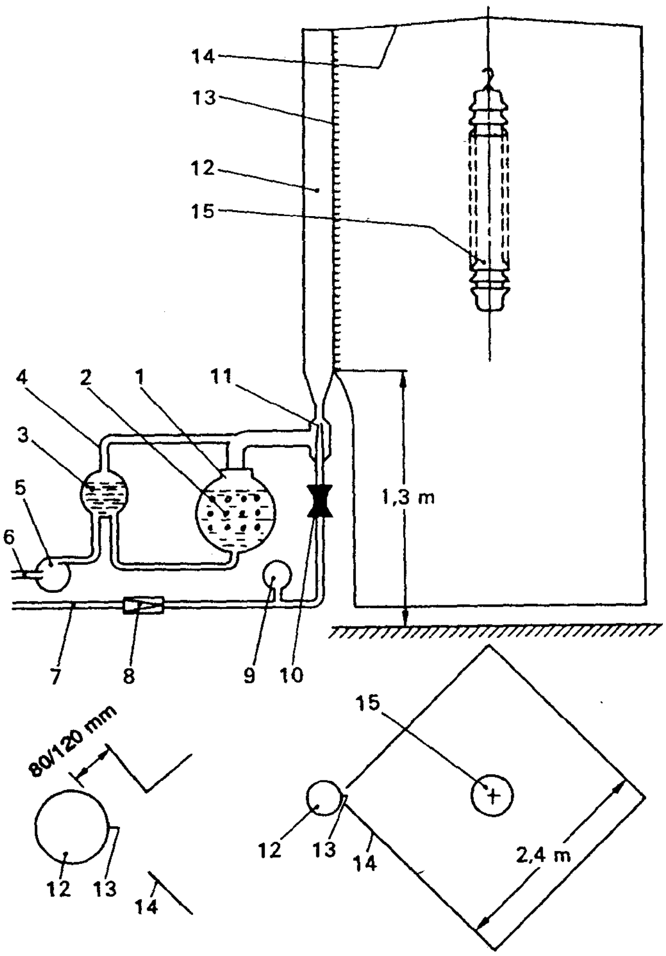


Figure 3 – Test layout for inclined insulators



1 = low-pressure boiler, capacity about 20 l

2 = electrical heater: 12 heating coils, each of 3 kW

3 = feed-water regulator valve

4 = pressure-equalizing pipe

5 = boiler feed pump: 50 l/h, 1bar

6 = connection for softened water

7 = connection for compressed air

8 = adjustable compressed-air reduction valve

9 = pressure gauge: 0-5 bars

10 = compressed-air valve, electric remote control

11 = injector nozzle: 7.5/16 mm diameter

12 = multipart nozzle pipe. Three nozzle pipes, each of 1.5 m length, and one intermediate pipe without nozzles for elevated installation. Overall total height from ground: 11 m; internal diameter of the lower pipe: 120 mm; internal diameter of the pipes reduced in steps to 50 mm for the upper pipe

13 = nozzle, internal diameter: 1.6 mm; distance between adjacent nozzles: 30 mm

14 = plastic tent

15 = test object

Figure 4 – Typical arrangement of steam-fog generator

Appendix A

Supplementary information on the assessment of the requirement for the testing plant

Many laboratories have provided measurements of the highest leakage current pulse amplitudes I_h occurring on a polluted insulator throughout the duration of all individual withstand tests in withstand conditions (see appendix B), which have been examined. The table below gives for the different levels of the electrical surface stress and for the specified conditions of the testing plant (clause 6) the maximum I_h values ($I_{h\ max}$) recorded on all insulator types in any test position.

Specific creepage distance* – L_s mm/kV	$I_{h\ max}$ A_{peak}
16 20 25	0,55 0,85 1,35

* Creepage distance divided by the product of the test voltage and $\sqrt{3}$.

NOTE - These $I_{h\ max}$ values may be exceeded when an insulator is tested in conditions more critical than those mentioned above, for example when the flashover probability is higher than that corresponding to a withstand test in withstand conditions.

If the ratio $I_{sc}/I_{h\ max}$ is considered, I_{sc} being defined in 6.2, its limit value, above which test results (e.g. withstand voltage or withstand degree of pollution, see appendix B) are no more influenced by the ratio itself, can be determined. On the basis of the available laboratory experience, this limiting value is estimated as equal to 11 in the range of the electrical surface stress given in the table above.

As regards the ratio I_c/I_{sc}, the specified limits are usually met by several testing plants. In particular the lower limit is generally complied with due to the amount of the equivalent source capacitance, the lumped capacitance (bushing and voltage divider) and the stray capacitances of the circuit.

Appendix B

Determination of the withstand characteristics of insulators

Sections Two, Three and Four deal with the verification of the specified withstand degree of pollution, at the specified test voltage. In addition, however, the characteristics of an insulator can be determined over a range of voltage, or, in other words, over a range of specific creepage distances of the insulator itself. To do this the maximum withstand degree of pollution is measured at different voltage levels or, in some other cases, the maximum withstand voltage, or the 50 % withstand voltage, at different reference degrees of pollution values. Examples of procedures for such evaluations are described below.

Directions for checking the laboratory equipment for artificial pollution tests, when requested, are given in clause B.3.

B.1 Determination of the maximum withstand salinity at a given test voltage

The insulator shall be subjected to a number of tests at a given test voltage and at different salinities among those listed in clause 7. The test shall be performed according to clause 11.

The tests can be carried out in any sequence providing that:

a) when the total number of flashovers at any salinity reaches two, no further tests shall be carried out at the same or higher salinities;

b) when the total number of withstands reaches three, no further tests shall be carried out at the same or lower salinities.

The preconditioning process (see clause 10) shall be performed on the insulator before the determination of the maximum withstand salinity.

NOTE - When test series of long duration are performed, the insulator may need cleaning, as recommended in 5.2, and subsequently preconditioned whenever the conditions of the insulator require it.

If four withstands are recorded at 224 kg/m^3 salinity, the maximum withstand salinity shall be assumed as being equal to or greater than 224 kg/m^3. If one flashover and three withstands are recorded at 224 kg/m^3 salinity, this salinity shall be considered as the maximum withstand salinity.

B.2 Determination of the maximum withstand voltage, or of the 50 % withstand voltage, at a given reference layer conductivity, or at a given reference salt deposit density

B.2.1 *Maximum withstand voltage*

A series of tests shall be carried out on insulators having a given value of reference layer conductivity or reference salt deposit density. Each test shall be carried out at any one of a number of voltage levels, each of which shall be about 1,05 times the next lowest value.

Each test shall be made in accordance with clause 18.

The tests can be carried out in any sequence provided that:

a) when the total number of flashovers at any voltage reaches two, no further tests shall be carried out at the same or higher voltage levels;

b) when the total number of withstands at any voltage reaches three, no further tests shall be carried out at the same or lower voltage levels.

B.2.2 *50 % withstand voltage*

The insulator shall be subjected to at least ten "useful" tests at a given reference degree of pollution. The test shall be made in accordance with 18.2. The applied voltage level in each test shall be varied according to the up-and-down method. The voltage step shall be about 10 % of the expected 50 % withstand voltage.

The first "useful" test should be selected as being the first one that yields a result different from the preceding ones. Only this test and at least nine of the following tests should be taken as useful tests to be considered to determine the 50 % withstand voltage. The calculation of the 50 % withstand voltage shall be made using the following formula:

$$U_{50\,\%} = \frac{\Sigma\,(n_i \times U_i)}{N}$$

where:

U_i is an applied voltage level

n_i is the number of groups of tests carried out at the same applied voltage level U_i

N is the number of useful tests

More details on the up-and-down method and processing of the relevant results are to be found in IEC 60-1.

NOTE - The 50 % withstand voltage is often referred to as "50 % flashover voltage".

B.3 Withstand values of reference suspension insulators

To facilitate checking of existing or new laboratory equipment for artificial pollution tests, ranges of values for the withstand characteristics of a few reference suspension insulators are given in table B.1. These values, which are based on results from several laboratories, located at less than 1 000 m altitude above sea level, were obtained according to the recommendations given in this standard.

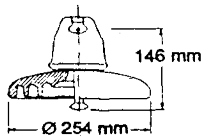
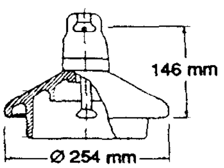
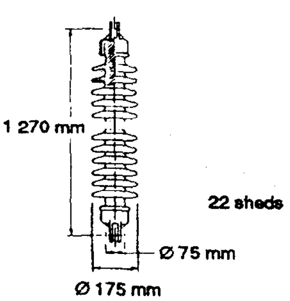
NOTE - The reference suspension insulators given in table B.1 are not to be seen as representative of their respective classes. Their choice does not imply by itself any judgement of merit or any assumption that they might have better performance than other similar types in tests or in operating conditions.

Laboratories starting artificial pollution tests or which are located at altitudes higher than 1 000 m above sea level, or which do not commonly use one of the above mentioned test methods, may expect, in the relevant results, some variation from the ranges of values given in table B.1.

NOTE - IEC 60-1 states that no humidity correction shall be applied for artificial pollution tests and informs that air density correction for such tests is under consideration.

Table B.1 - Ranges of values of withstand characteristics of reference suspension insulators in artificial pollution tests

Single strings in vertical arrangement

Insulator type and number of units per string	Specific creepage distance	Applied voltage (r.m.s.)	Salt fog test method	Solid layer methods[1]			
				Procedure A		Procedure B	
			Maximum withstand salinity	Maximum withstand layer conductivity	Maximum withstand salt deposit density	Maximum withstand salt deposit density	Maximum withstand layer conductivity
	mm/kV	kV	kg/m³	µS	mg/cm²	mg/cm²	µS
	16	95	7-14	7–14	0,02-0,04		
9 units Overall creepage distance: 2 630 mm	20	76	20-40	14–28	0,04-0,1		
	20	101	28-56	14–28	0,04-0,1		
9 units Overall creepage distance: 3 510 mm	25	81	80-160	20-40	0,06-0,15		
	20	85	14-28	14–40	0,025-0,08		
1 unit Overall creepage distance: 2 960 mm	25	68	40-80	28–56	0,06-0,13		

1) The values of maximum withstand layer conductivity and maximum withstand salt deposit density for procedure A refer to tests carried out using the composition of the suspension given in 13.1. Values for procedure B are still under consideration.

Appendix C

Measurement of layer conductivity for checking the uniformity of the layer

The device for the measurement of the layer conductivity (*K*) of the wet layer on an insulator surface basically consists of a probe and a meter. As an indication a possible arrangement of such a device is described in the following:

- *Probe* (figure C.1)

  Two spherical stainless steel electrodes, 5 mm in diameter and having a distance of 14 mm between centres, overhanging from the probe shall be pressed by hand against the insulator surface. A constant surface pressure is obtained by means of a spring mechanism developing a force of about 9 N.

- *Meter* (figure C.2)

  A voltage source stabilized by a Zener-diode at 6,8 V supplies the current across the electrodes and the surfaces between them. The measuring instrument with a full scale deflection at 50 µA is protected by a diode in parallel.

  For thin films with a layer conductivity of 50 µS, the resistance between the electrodes is assumed to be 32,7 kΩ: the respective values for 100 µS and 500 µS layer conductivity are 16,35 kΩ and 3,27 kΩ. Each of these resistances is combined with a test battery inserted in parallel with the electrodes. The selector switch is used to choose the full scale deflection for the respective measuring ranges.

The above measurement of layer conductivity shall be carried out at different points of the insulator surface. The polarization effect shall be taken into account by a momentary operation of the meter push-button.

The uniformity of the layer is deemed acceptable when the difference between each of the measurements and their average, as a percentage of the average value, does not exceed the limits ±30 %.

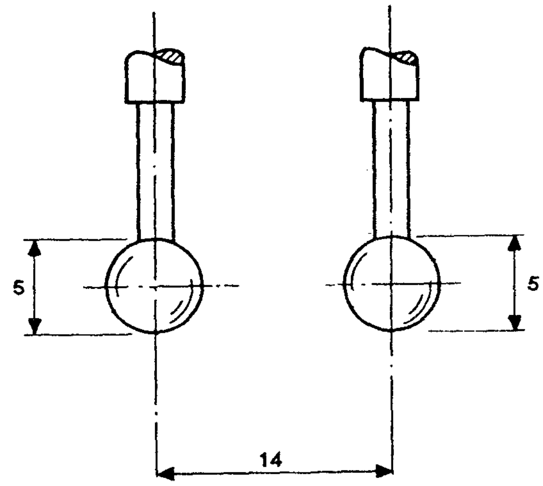
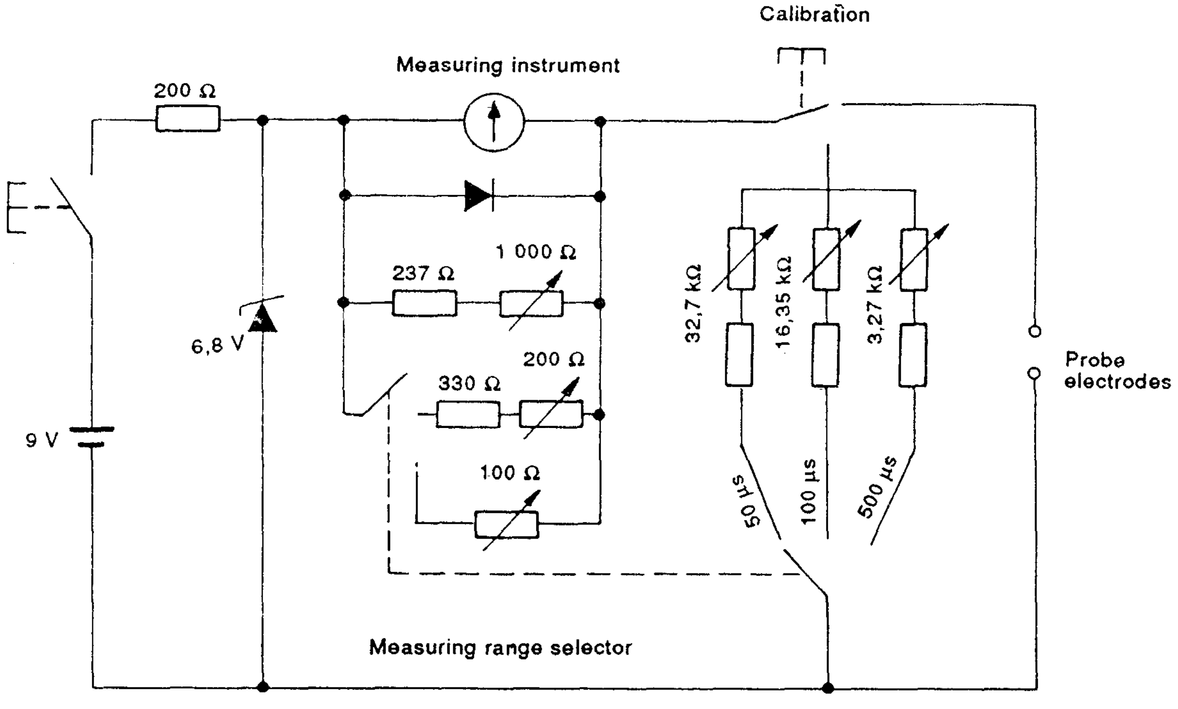


Figure C.1 – Arrangement of the probe electrodes (all dimensions in mm)



Meauring instrument
Charging rate 50 µA
Internal resistance 1,5 kΩ

Figure C.2 – Circuit diagram of the meter

Appendix D

Additional recommendations concerning the solid layer method procedures

The additional recommendations given below go more deeply into the practices of the solid layer methods, providing criteria for auxiliary controls during the tests and preventing users not yet sufficiently expert in this field from possible inaccuracies.

Clauses D.1 and D.2 are general, while the remaining clauses D.3 to D.6 mainly refer to procedure B of the solid layer methods.

D.1 Contamination practice

When the spraying or "flow-on" practice is used, the operation can be performed on the insulator placed in the chamber in its test position. When the dipping practice is used, the insulator shall be contaminated before its erection in the test chamber. If the insulator consists of several units in series, each of them shall be dipped separately and then be kept with its axis vertical for the duration of dripping of the contaminant and until the layer is completely dry.

If, after the contaminating operation, a blotched layer is observed on the insulator, its surface shall be washed and cleaned again according to 5.2. Then one or more trial contaminations are performed, each followed by the relevant washing, until a continuous layer is obtained on the insulator. The tests may then be started. Experience has shown that, in general, it suffices to repeat the operation several times in order to have the insulator surface ready to be contaminated in a satisfactory way, without using any preconditioning process.

D.2 Drying of the pollution layer

Natural drying of the pollution layer on the insulator may be sufficient, provided that it lasts long enough (6 h - 8 h) while the relative humidity around the insulator is kept not higher than 70 %. Humidity values lower than this level allow shorter drying times.

If hot air is used to accelerate the drying of the layer, the method for producing hot air shall not result in the deposition of material which affects either the wetting of the insulator surface or the degree of pollution. For instance, some flame combustion may generate oil substances which may inhibit the wetting of the insulator surfaces.

Finally the speed of the hot air flow is to be controlled, in order to prevent the removal of any content of the layer from the insulator surface.

D.3 Check of the wetting action of the fog

In cases of very low or high outdoor temperature, especially with poor thermal insulation of the chamber, high altitude, or the presence of turbulence in the chamber, a direct check of the wetting action of the fog on the test insulator may be required.

To this effect, a dummy insulator consisting of a string of at least two units of the standard cap and pin type of table B.1 contaminated at the *SDD* value equal to 0,07 mg/cm² shall be put unenergized in the test chamber, in place of the test insulator, at the same average height from the floor. While the fog generator is working as in a real test, the current flowing through the wet layer of the dummy insulator is measured according to the procedure given in 16.1. The increase of the layer conductance in time shall be monitored and compared with the reference curve given in figure D.1. If necessary, a re-adjustment of the fog input rate shall be carried out to ensure that the measured curve matches the reference one.

D.4 Fog input in the test chamber

The fog shall be produced by steam generated by boiling water in open tanks or by steam admitted at low velocity through large diameter spray nozzles. The fog input in the test chamber shall be allowed only after the steam generation has reached its steady rate. Therefore, when the steam is produced by tanks, they shall be kept covered until the water inside reaches boiling point.

The insulator shall be positioned so that the visible fog surrounds it as uniformly as possible.

The temperature rise in the test chamber, measured at the height of the test object, shall not exceed 15 K by the end of the test.

D.5 Minimum duration of the withstand test

A direct evaluation of the minimum time a test shall last to be considered as a withstand test, can lead in some cases to times shorter than prescribed in 18.2. To this effect, measurements of the peaks of the surge current on the energized test insulator shall be performed during the test. After the maximum peak is reached, the surge current diminishes owing to the washing of the layer in progress after its wetting. When the current peaks have decreased to values permanently lower than 70 % of the maximum peak recorded, the withstand of the insulator is definitive and the test can be stopped.

D.6 Evaluation of the reference salt deposit density (*SDD*)

The pollution layer shall be removed completely from the chosen area of the insulator. To this effect the area shall be wiped at least three consecutive times.

As an indication, 2-4 litres of demineralized water per square metre of the cleaned surface can be used for dissolving the collected deposit. The effectiveness of the removal operation can be checked by making successive measurements of the residual deposit.

Every contaminating practice leads to some difference in the *SDD* values measured separately, on the upper and lower surfaces of the insulator. This difference is affected both by the insulator shape and the type of the contaminating suspension (see clause 13). It is suggested that the ratio between a local measurement of *SDD* and that on the whole area of the insulator be checked as lying in the range 0,7-1,3.

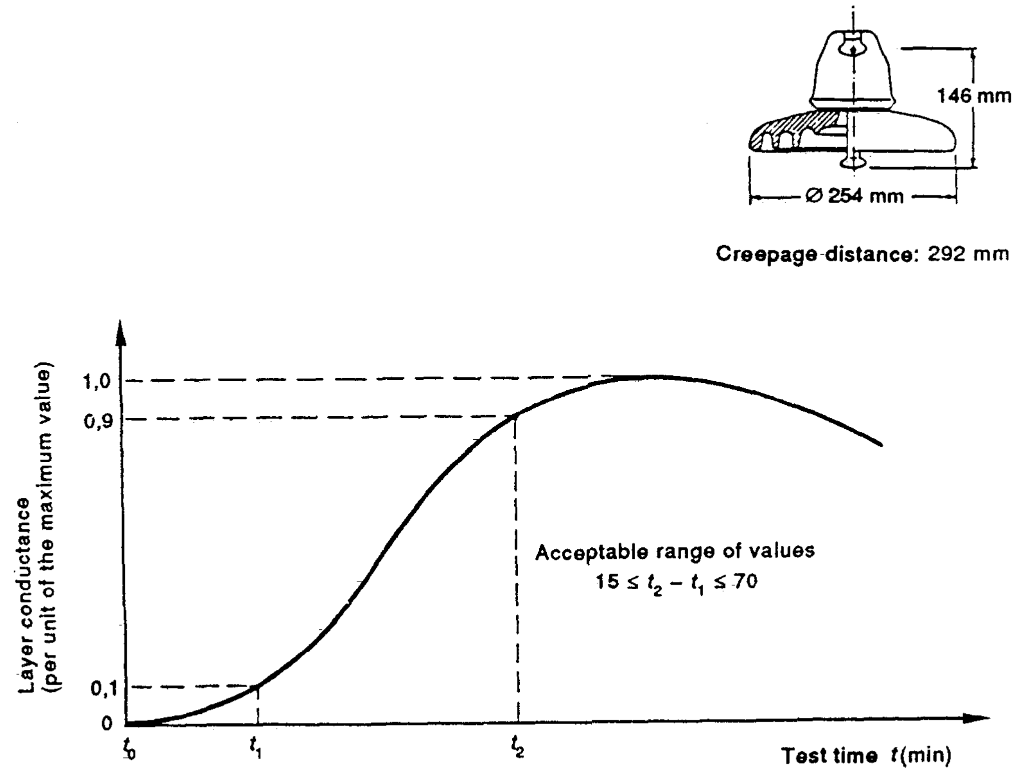


Figure D1 – **Control of the wetting action of the steam fog: layer conductance recording during the test on the chosen dummy insulator (standard type of Table B.1)**

(*Continued from second cover*)

While adopting the text of the International Standard, the Committee decided to make the following textual correction:

3.3 Specific creepage distance (L_s) of an insulator

The overall creepage distance L of an insulator divided by highest system voltage and expressed in mm/kV.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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